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A COMPARISON OF THE SENSITIVITY OF TWO SIMILAR OBJECTIVE FORECA--ETC(U)
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JTWC 74-4

A COMPARISON OF THE SENSITIVITY OF TWO SIMILAR OBJECTIVE FORECAST TECHNIQUES

BY

LCDR LEO H. CRAIGLOW, JR., USN

MAY 1974

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ABSTRACT

A number of computerized objective forecast techniques are available to assist the JTWC in the preparation of warnings. Of concern is the sensitivity of these techniques to errors in the warning and history positions.

Two techniques, TSGLOB and TYMOD, were selected for testing. Both techniques utilize the 24-hour global band upper air progs (GBUA) provided by FLENUMWEACEN Monterey, California. After selecting a GBUA field and running control forecasts for both techniques, errors of six and 12nm were introduced into the warning and history position, both individually and collectively.

The results showed that TYMOD was less sensitive to positioning errors than TSGLOB. In addition, the TYMOD errors tended to reach a maximum about +48 hours and then decrease in magnitude thereafter.

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1. BACKGROUND

The relatively small number of personnel assigned to the Joint Typhoon Warning Center, coupled with an area of responsibility encompassing the most climatologically active tropical cyclone region in the world, requires efficient utilization of both manpower and time. Towards this end, a number of computerized objective forecast techniques have been developed to assist the Typhoon Duty Officer (TDO) in the preparation of his forecasts. While these objective forecast techniques are being processed on a CDC 3100 Computer, the TDO is freed to study the surface and upper air analyses and prognoses and prepare his preliminary forecast track.

Of major concern to the JTWC is how sensitive these objective forecast techniques are to minor variations in the warning position. The warning position is an extrapolated position based on past history and a fix position made, optimally, 2-1/2 hours before warning time. Fixes can be made by various means, e.g., penetration by weather reconnaissance aircraft, satellite, sea, land, or airborne radar, etc. Each of these methods of positioning a tropical cyclone has an average degree of accuracy associated with it. During 1972, the average JTWC warning position error for 717 forecasts was 25 nm, or a little more than 0.4 degrees of latitude.

2. TECHNIQUES TESTED

Two objective techniques, TSGLOB (Tropical Storm, Global Band) and its successor, TYMOD (Typhoon Modified), were chosen for sensitivity testing. TSGLOB was developed by Fleet Weather Central, Pearl Harbor. It is basically a point-source forecast technique that utilizes the u and v wind components of the fine mesh (2-1/2° x 2-1/2° latitude/longitude grid) Global Band Upper Air (GBUA) progs produced by Fleet Numerical Weather Central at Monterey, California.

A subroutine within TSGLOB extracts the u and v components of the wind one-half grid length in each cardinal direction from the warning position plus the u and v wind components at the warning position. By simple linear averaging, representative u and v wind components are obtained. If there is no 12-hour history position, the program advects the warning position forward in time, using three-hour time steps, out to 48 hours employing the steering flow in the GBUA fields for each of six levels. These levels are 700mb, 500mb, 400mb, 300mb, AVG1, and AVG2. AVG1 is the average of the 700mb, and 500mb fields. AVG2 is the average of AVG1 plus the 700mb, 500mb, 400mb, and 300mb fields. Output is provided for all six levels at 21-hour intervals in the following format: The storm's forecast latitude and longitude, steering flow direction and speed, and the wind direction at the storm's forecast position.

If a 12-hour history is inputed, TSGLOB advects the representative u and v wind components at the warning position backwards in time for 12 hours. A bias wind (calculated steering wind that moved the storm for the past 12 hours minus the wind for the particular level at the midpoint of the 12-hour history track) is then computed for each of the six levels. The level with the minimum bias flow (i.e., the level with the minimum vector error) is selected as the best steering level. Utilizing the minimum bias flow level, TSGLOB then advects the warning positions forward in time using the same procedures as when there was no history. Output for TSGLOB with history contains the same information as the output without history plus the direction and speed of bias flow, the bias flow calculated at the 12-hour history position, and a designation as to which level provides the best steering flow.

Early in the use of TSGLOB, it became apparent that possible improvements to this program could be made. Numerous areas for improvement were investigated and the following four major changes

were made to the program:

a. A 24-hour history position was added to provide more continuity.

b. A weighting system for computing *u* and *v* components of the wind was developed based on the 24-hour and the 12-hour past movement of the tropical cyclone. These weighting factors were determined from a test of 30 cases chosen at random from the 1972 tropical cyclone data. The greatest weight (2) was given to the center position. The next greatest weight (1) was assigned to the two cardinal points toward which the storm was moving. The least weight (1/2) was used for the two cardinal points from which the storm was moving. For example, if a typhoon was moving toward the northwest, the *u* and *v* components of the wind to the north and west of the storm would receive greater weight then the *u* and *v* components to the south and east.[1]

c. A method for determining the rate of change of movement of the tropical cyclone over the past 24 hours was incorporated into the program. The warning position and 24-hour history position are averaged and compared to the 12-hour history position. The differences are then used to determine whether the system has accelerated or decelerated and moved to the right or left of track. These differences are then combined to yield a function that is added linearly to each forward time step.

d. The forecast period was extended to 72 hours to satisfy JTWC operational requirements. This provided one more objective technique to assist the TDO in preparing the 72 hour outlooks.

The above changes, plus numerous minor revisions to the basic program, resulted in TYMOD, which was used operationally during the 1973 tropical cyclone season.

1 Based on an analysis of the 1973 TYMOD statistics, the weighting factors were determined to have been adversely influencing the TYMOD forecasts. Therefore, the weighting factors have been removed from the program and will be recomputed at the conclusion of the 1974 season.

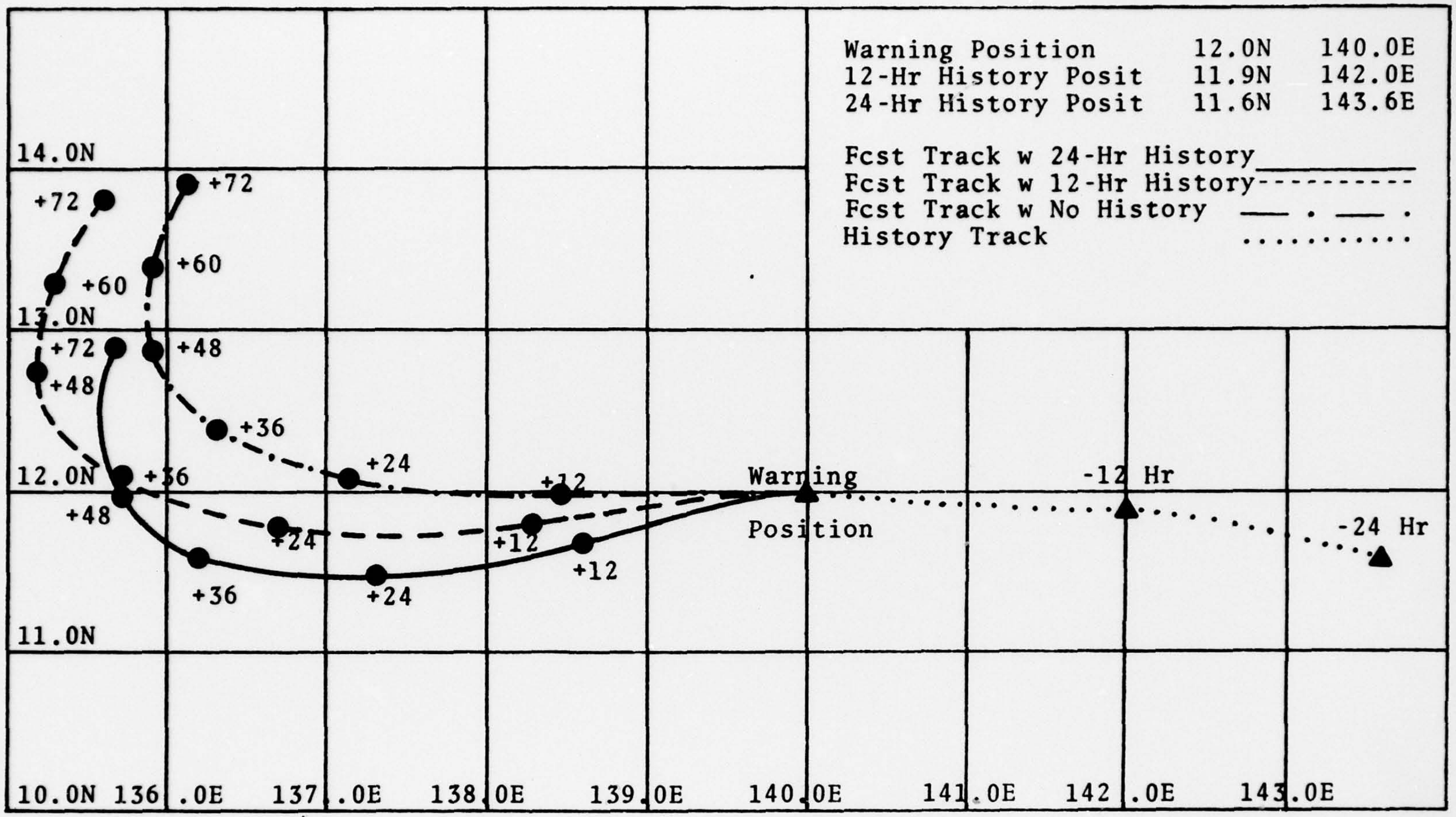

Figure 1. Control Forecast Tracks for TYMOD Using 400mb Steering Flow

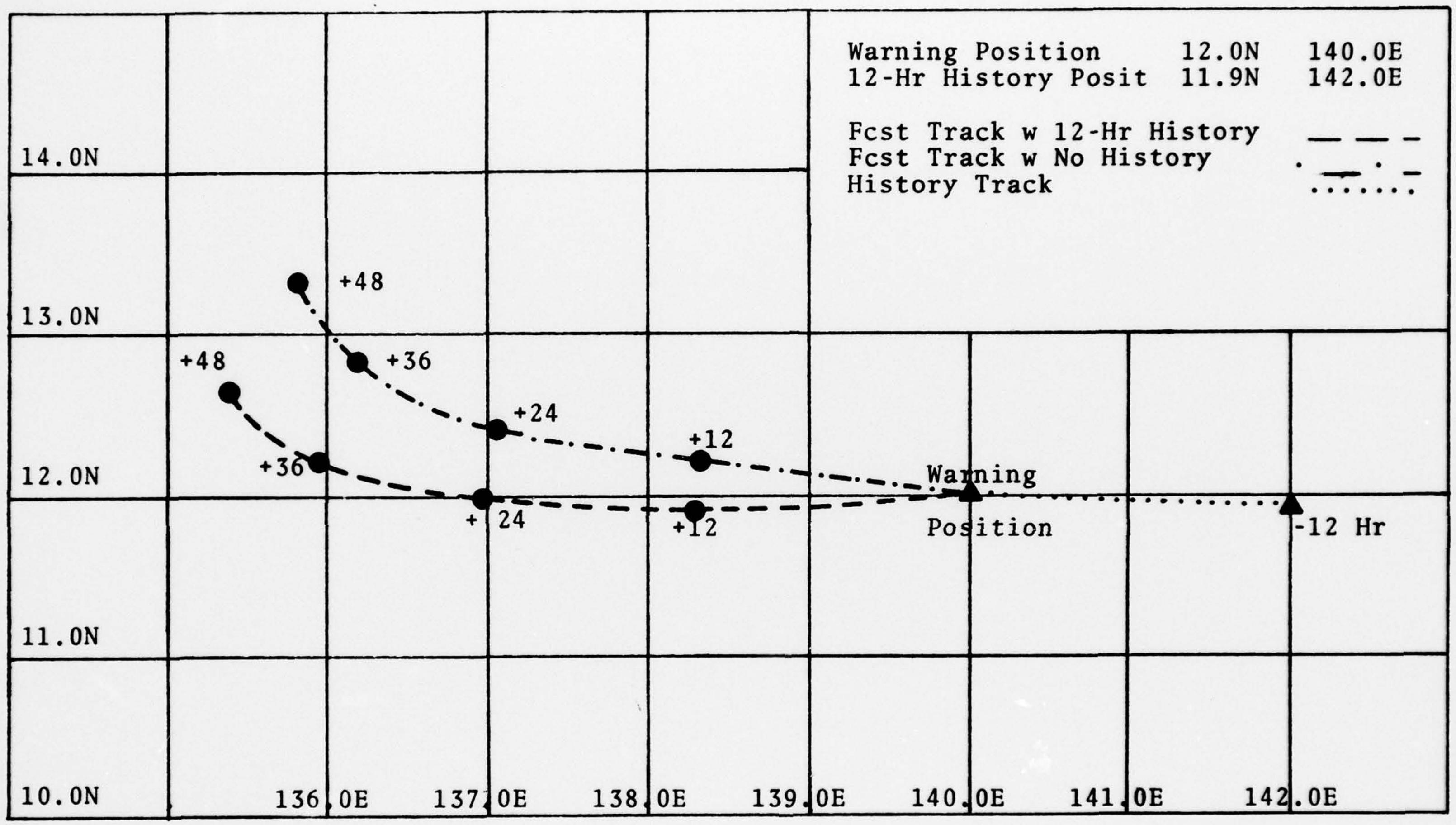

Figure 2. Control Forecast Tracks for TSGLOB Using 400mb Steering Flow

3. TEST PROCEDURES

The following three hypotheses were formulated prior to the start of testing:

a. TYMOD would be less sensitive to bogused warning and history position errors than TSGLOB due to the incorporated changes.

b. Forecast position errors, generated by errors introduced into the warning position, would be greater than for errors introduced into the history positions.

c. Forecast position errors would increase with time.

The 24-hour GBUA prog fields for 030000 GMT, 3 January 1973, were selected for the test. No tropical cyclones existed at that time; however, since both models basically advect a point-source, this was not considered detrimental. In addition, the test was not designed to ascertain the accuracy of the two techniques, only how sensitive they were to small deviations in the warning and history positions.

Upon selection of the standard warning, 12-, and 24-hour history positions, control forecast tracks were run on Guam's CDC 3100 Computer for both techniques; the results of which are displayed in Figures 1 and 2. Both TYMOD and TSGLOB selected 400mb as the best steering level for the control forecast tracks as well as for all subsequent test runs.

Errors of 0.1 and 0.2 degrees (6 and 12 NM respectively) were introduced into the warning, 12-, and 24-hour history positions as shown in Table I. All errors were introduced along the four cardinal points. Thirty-six cases were run for TYMOD and 20 for TSGLOB, the difference being due to TYMOD having a 24-hour history position.

Position Where Error Introduced	TYMOD						TSGLOB			
	24-Hr History		12-Hr History		No History		12-Hr History		No History	
	No. of Cases	Error	No. of Cases	Error	No. of Cases	Error	No. of Cases	Error	No. of Cases	Error
Warning	4	.1	4	.1	4	.1	4	.1	4	.1
Warning	4	.2	4	.2	4	.2	4	.2	4	.2
12-Hr History	4	.1	4	.1	-	-	4	.1	-	-
12-Hr History	4	.2	4	.2	-	-	4	.2	-	-
24-Hr History	4	.1	-	-	-	-	-	-	-	-
24-Hr History	4	.2	-	-	-	-	-	-	-	-
Warning & 12-Hr History	4	.1	4	.1	-	-	4	.1	-	-
Warning & 24-Hr History	4	.1	-	-	-	-	-	-	-	-
12-Hr History & 24-Hr History	4	.1	-	-	-	-	-	-	-	-
TOTAL CASES	36		20		8		20		8	

TABLE I. Distribution and Magnitude of Errors Introduced into TYMOD and TSGLOB

Error Introduced (TYMOD / TSGLOB)	Average Deviations from the Control Forecast Positions (NM)						No. of Cases
	12 Hr	24 Hr	36 Hr	48 Hr	60 Hr	72 Hr	
Warning (w No History)	7.2 / 8.0	7.2 / 7.5	6.5 / 5.9	4.8 / 5.9	2.3 / --	3.8 / --	8 / 8
Warning (w 12-Hr History)	16.5 / 17.6	21.6 / 22.3	23.0 / 24.5	23.1 / 25.7	23.3 / --	25.7 / --	8 / 8
Warning (w 24-Hr History)	11.6 / --	15.5 / --	15.2 / --	14.6 / --	12.2 / --	12.3 / --	8 / 0
12-Hr History	8.1 / 8.6	13.4 / 15.0	17.6 / 18.6	17.4 / 20.3	18.5 / --	19.7 / --	8 / 8
12-Hr History (w 24-Hr History)	0.0 / --	0.0 / --	4.2 / --	4.5 / --	4.7 / --	6.3 / --	8 / 0
24-Hr History	3.3 / --	7.8 / --	9.8 / --	8.7 / --	6.5 / --	7.7 / --	8 / 0
Both Posits (w 12-Hr History)	16.8 / 14.7	19.5 / 23.3	24.6 / 27.3	26.0 / 28.5	26.7 / --	22.5 / --	4 / 4
2 of 3 Posits (w 24-Hr History)	4.7 / --	8.7 / --	9.1 / --	9.2 / --	9.1 / --	8.6 / --	12 / 0
Overall Average (w 12-Hr History)	13.2 / 13.4	17.9 / 19.6	21.1 / 22.7	21.4 / 24.1	22.1 / --	22.6 / --	20 / 20
Overall Average (w 24-Hr History)	4.9 / --	8.0 / --	9.0 / --	9.2 / --	8.2 / --	8.7 / --	36 / 0

TABLE II. Summary of Average Deviations from the Forecast Positions for TYMOD and TSGLOB

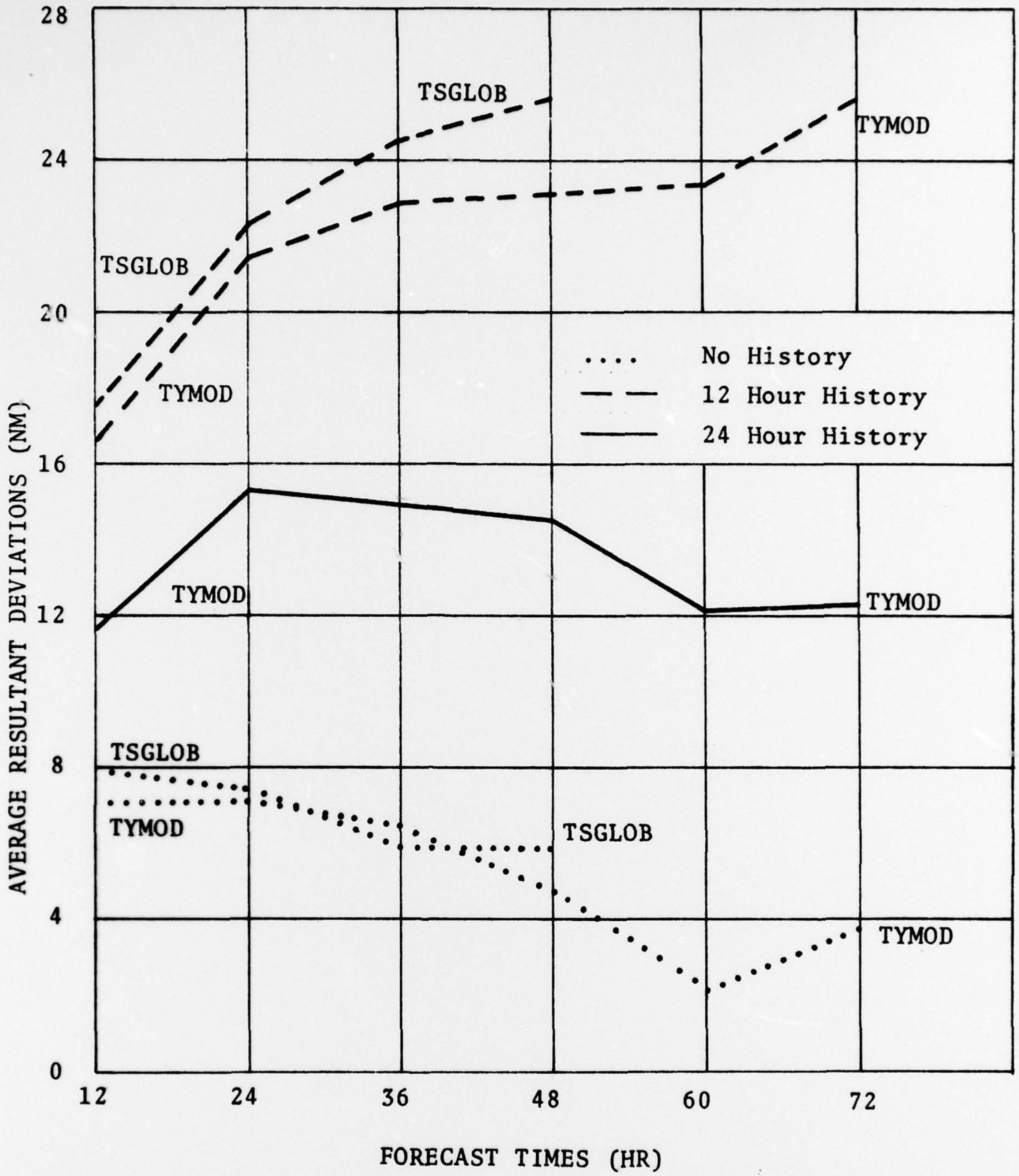

Figure 3. Average Forecast Position Deviations Resulting from Bogused Error in the Warning Position

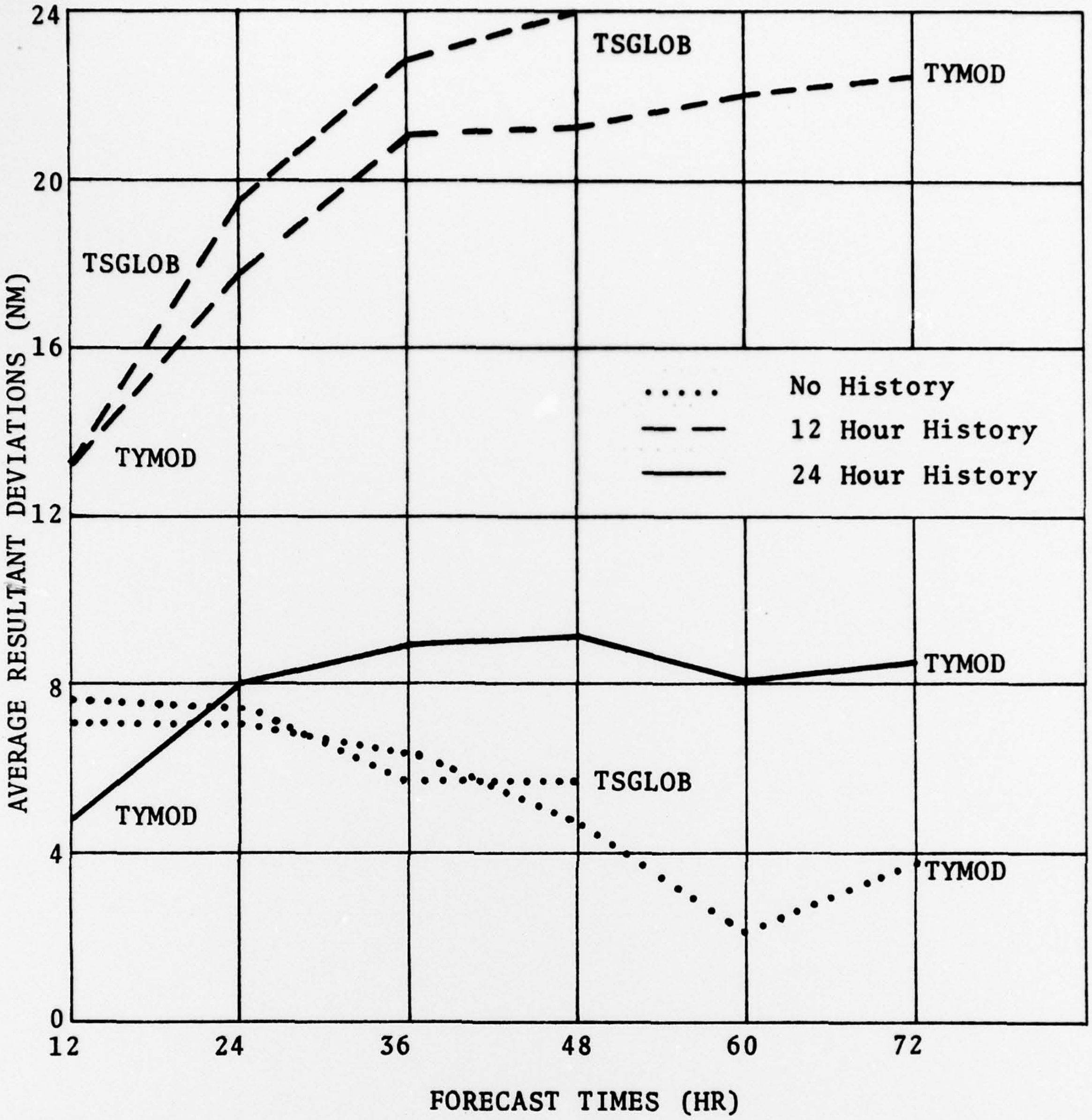

Figure 4. Overall Comparison of Average Deviations from the Control Forecast Positions

4. RESULTS

All forecast positions were plotted and compared to their respective control forecast positions. Table II depicts the resultant average deviations at each 12-hour forecast time for both TYMOD and TSGLOB for each category in which a warning or history position was varied. In only two out of the 20 like cases (10%) did TSGLOB have an average deviation less than TYMOD. These occurred at:

a. The 36-hour forcast position where the error was introduced into the warning position with no history; and

b. The 12-hour forecast position where the error was introduced into both positions with 12-hour history.

A comparison between the "overall average" with 12- and 24-hour histories shows some marked differences. TYMOD with 24-hour history has an average deviation that is only 40.5% as large as TYMOD with 12-hour history and 38.8% as large as TSGLOB with 12-hour history. In addition, whereas the average deviations for both TYMOD and TSGLOB with 12-hour history continue to increase with time, TYMOD with 24-hour history peaks at 48 hours, hits a secondary minimum at 60 hours, and then starts to increase again. A check of each of the other TYMOD with 24-hour history categories listed in Table II shows this same basic pattern. The lone exception to this occurs where the 12-hour history position is varied. Even in this case, the average deviations are far below all other categories with history.

Figure 3 compares the forecast position deviations between TYMOD and TSGLOB when the error was bogused only into the warning position. From this figure it can be seen that TYMOD with 24-hour history is superior to all other categories with history by 32-36%. Figure 4 compares TYMOD and TSGLOB overall, when the errors were bogused at any position. In this case, TYMOD with 24-hour history was even superior to the no history average deviations at 12-hours.

5. SUMMARY

The results contained in the previous section clearly indicate the superiority of TYMOD over TSGLOB with respect to their sensitivity to positioning errors. Of the three hypotheses postulated in section 3, two proved correct, i.e., TYMOD was less sensitive to positioning errors than TSGLOB and an error bogused into the warning position did produce larger average forecast position deviations than for errors bogused into the history positions.

The hypothesis that deviations in the forecast positions would increase with time for all categories, however, proved false. Of the ten cases depicted in Table II for TYMOD, all either showed a decrease at some point or remained basically unchanged for at least 12 hours. For the five TSGLOB cases, only the case with no history and the error introduced into the warning position showed any decrease in average deviation.

Looking more closely at the resultant average deviations in TYMOD, of the five cases which include 24-hour history, four peaked at or before the 48-hour forecast position. Of these four, three bottomed out at the 60-hour forecast position and one reached a minimum at the 72-hour forecast position. The consistent behavior of TYMOD with 24-hour history is attributed to the rate of change of movement factory which is only incorporated into the 24-hour history output. In addition, 12- plus 24-history, together, provide better continuity than either one separately.

Overall, TYMOD with 24-hour history has proven itself it be less sensitive to positioning errors than any other category, with the exception of the case with no history. However, the maximum errors bogused into the warning and history positions were only one-half of the average warning position error 717 forecasts in 1972.[2] Based on a statisticaly analysis of 1972 data, and using pure linear extrapolation, it can be ascertained that errors in the 1972 warning position could have accounted for over 30% of the 24-hour mean vector error of 117nm.

The testing conducted on TYMOD and TSGLOB suggest that one answer to better forecasts are more reliable fixes, regardless of the platform. It can be assumed that the other objective techniques employed by the JTWC are, to varying degrees, also sensitive to errors in the warning and history positions. A reduction in fix error will result in a corresponding reduction in the warning postion error. This in turn, will reduce that portion of the objective technique error attributable to positioning error. The overall result will be better forecasts.

2 During 1973, the average warning position error for 390 forecasts was 24nm, a decrease of one nm over the 1972 statistics.

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CINCPACINST 3140.1L, "Tropical Cyclone Operations Manual", June 1973.

FLEWEACEN/JTWC, Annual Typhoon Report, Guam Marianas Islands, 1972 and 1973.